ECOLOGICAL NETWORK AND ECOSYSTEM SERVICES

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To address the growing challenges faced by near-future cities–such as floods, water shortages, and heat islands–urbanism and ways of dwelling must adapt. Currently, two main approaches are favoured: technological solutions and nature-based solutions. To adopt the second option, a good understanding of green infrastructure is essential. This research aims to analyse the ecological network of Maribor, with particular emphasis on ecological corridors. For this analysis, we investigated both the actual ecological network and people's perception of ecosystem services through spatial analysis using GIS tools and a survey. Most respondents expressed satisfaction with the availability and accessibility of green spaces. However, the maps indicate that, although Maribor is surrounded by many green areas, including several Natura 2000 sites, some central districts need improvement. It is recommended to establish green corridors in these areas to create both an ecological network and to enhance ecosystem services.

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EKOLOŠKO OMREŽJE IN EKOSISTEMSKE STORITVE

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Ključne besede:
ekosistemske storitve,
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zeleni koridor,
dobrobit,
zaznavanje,
Maribor

Za soočanje z naraščajočimi izzivi mest v bližnji prihodnosti – kot so poplave, pomanjkanje vode in toplotni otoki – se morata urbanizem in način bivanja prilagoditi. Trenutno prevladujeta dva glavna pristopa: tehnološke rešitve in na naravi temelječe rešitve. Za uveljavitev slednjih je ključno dobro razumevanje zelene infrastrukture. Namen raziskave je analizirati ekološko omrežje Maribora, s posebnim poudarkom na ekoloških koridorjih. V analizi smo preučevali dejansko ekološko omrežje ter zaznavanje ekosistemskih storitev med prebivalci. Izvedli smo prostorske analize z GIS-orodji in anketiranje. Večina anketirancev je izrazila zadovoljstvo z razpoložljivostjo in dostopnostjo zelenih površin. Kljub temu kartografski prikazi kažejo, da je Maribor sicer obdan s številnimi zelenimi območji, vključno z več območji Natura 2000, vendar nekateri osrednji mestni predeli potrebujejo izboljšave. Priporočena je vzpostavitev zelenih koridorjev na teh območjih, saj bi ti prispevali tako k oblikovanju ekološkega omrežja kot tudi k izboljšanju ekosistemskih storitev.

Univerzitetna založba Univerze v Mariboru

1 Introduction

Maribor is the economic, transportation, cultural and tourist centre of northeastern Slovenia and the second-largest city in Slovenia. Its geographically favourable and picturesque location on both banks of the Drava River has significantly contributed to its importance, where, at the transition from the pre-Alpine to the sub-Pannonian world, the narrow Drava valley widens into the Drava plain, in the north it passes through the border of the Podravska region hills with the Kozjak Mountains into the wine-growing region of Slovenske gorice, and in the south it ends at the forest ridge of the Pohorje Mountains (Kert, 1978; EU, 2023).

Research on ecological networks presents numerous opportunities, as it plays a crucial role in preserving biodiversity, adapting to climate change, and enhancing the quality of life in cities (Ignatieva et al., 2011; Pandey & Ghosh, 2023; Sturiale & Scuderi, 2019; Wang et al., 2024). When it comes to Maribor, there is a need to better understand how ecological networks contribute to sustainable city development and strengthen the resilience of urban areas.

At the European level, Natura 2000 is a European ecological network designed to preserve biodiversity, as biodiversity in Europe is declining. Floodplain forests and wetlands are disappearing, and the cultural landscape is undergoing significant changes. To stop and reverse the trend of plant and animal species extinction, the European Union established the Natura 2000 network of sites (Debeljak, 2025). In 1992, the Habitats Directive was adopted, which sets out criteria for the protection of rare, endangered or endemic species of wild animals and plants as well as their habitats. Previously, in 1979, the Bird Directive aimed to protect wild birds present in the EU and their habitats. Together, the two directives form the framework for nature conservation in the EU, the Natura 2000 network. Slovenia has implemented both directives with the Regulation on Special Areas of Conservation (ZRSVN, n.d.).[3] Nonetheless, few reflections exist at the city level in former socialist states on developing and connecting green areas of biological interest. This creates a research gap in understanding how ecological infrastructure functions in medium-sized Central European cities, such as Maribor.

Two main research questions will lead our study:

What is the Ecology Network in Maribor like?

How do people perceive the Ecological Network in Maribor?

2 Ecological network and ecosystem services

The United Nations Environment Program defines ecosystem services as the benefits derived from ecosystems. They are classified into four different categories: provisioning (water, food), regulating (climate and flood/drought regulation, water purification), cultural (aesthetic, educational, recreational), and supporting (soil formation, nutrient supply, water cycles) (UNEP, 2005).

In social-ecological networks (SENs), the ecosystem services can be modelled in different ways, chosen to fit the study's aim and context. It provides a promising approach to representing the complex ecological, social, and social–ecological relationships that influence the service supply of ecosystems. In this context, ecosystem services may be represented as links, nodes, node attributes, or emergent properties of the network (Felipe-Lucia et al., 2022).

Figure 1: Ecosystem services provided by a tree, illustrating provisioning, regulating, supporting and cultural benefits.
Source: Vokřál, 2025

Previous studies have demonstrated that ecological and socio-ecological networks are crucial for comprehending biodiversity conservation and sustainable land use. Research indicates that stakeholder participation, governance structures, and institutional power significantly influence how networks like Natura 2000 operate in practice (Laktic et al., 2020). Research indicates that stakeholder participation,

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Beyond Slovenia, landscape fragmentation remains one of the greatest threats to habitats, biodiversity, and ecosystem services (Laktić et al., 2020). To address this challenge, greater attention needs to be paid to the dynamic processes of socio-ecological systems (Xiu et al., 2017).[7]

3 The ecology network in Maribor

To answer the question of what the ecological network is like in Maribor, we drew several maps representing both the land cover, especially green areas, and the protected areas.

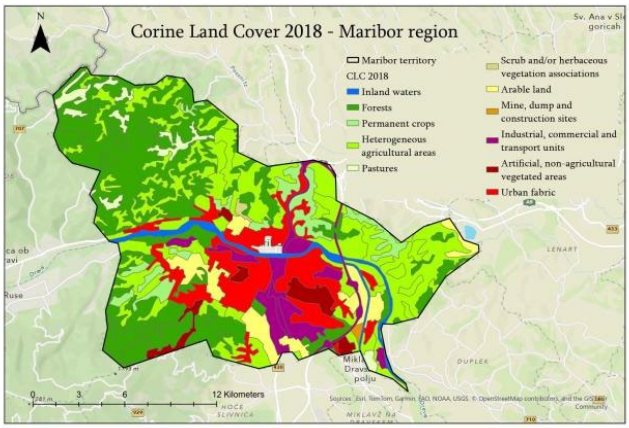

Figure 2: Map of Corine land cover 2018 in the Maribor region.
Source: S. Yakovlieva, 2025

Figure 2 illustrates land-cover patches within the municipality of Maribor. The municipal boundary at the NUTS 3 level was obtained from the Eurostat official dataset, while land cover data was derived from the Copernicus Land Monitoring Service (Corine Land Cover). The map highlights the spatial distribution of urbanised and non-urbanised areas.

Figure 3 illustrates Natura 2000 protected areas within the municipality, which are localised along the Drava River and part of the Pohorje Mountains.

Figure 4 shows several ecological areas, mainly concentrated near the city of Maribor, some of which overlap with the Natura 2000 protected areas.

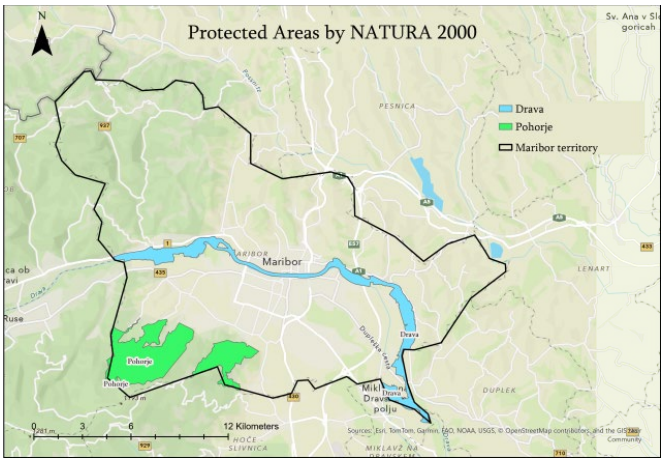

Figure 3: Map of the protected areas by Natura 2000.
Source: S. Yakovlieva, 2025

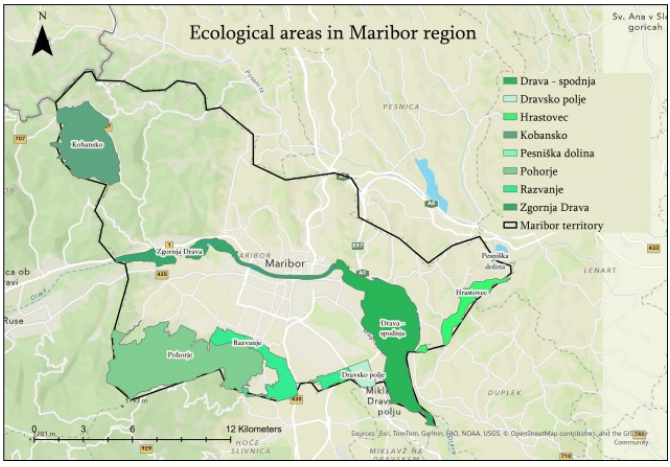

Figure 4: Map of ecological areas in the Maribor region.
Source: S. Yakovlieva, 2025

Figure 5 gives an overview of all green areas within the municipality. To better illustrate green areas within the city border, a more detailed scale is applied in the following map (Figure 6).

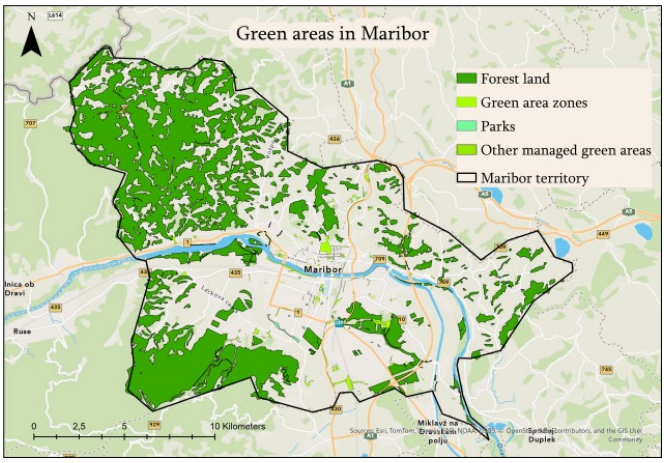

Figure 5: Map of green areas in Maribor.
Source: S. Yakovlieva, 2025

Figure 6: Map of green corridors in the central urban zone of Maribor.
Source: S. Yakovlieva, 2025

Figure 6 presents the green corridors, demonstrating the level of connectivity between patches of green areas in the central urban zone. The results indicate that ecological networks in Maribor are relatively well-connected.

Figure 7: Map of green corridors along the Drava river in Maribor.
Source: S. Yakovlieva, 2025

The map in Figure 7 focuses on the Drava River, which connects the northern and southern parts of the city. It highlights adjacent green spaces and pedestrian zones along the river, which provide important ecosystem services related to recreation and contribute to mental and physical health.

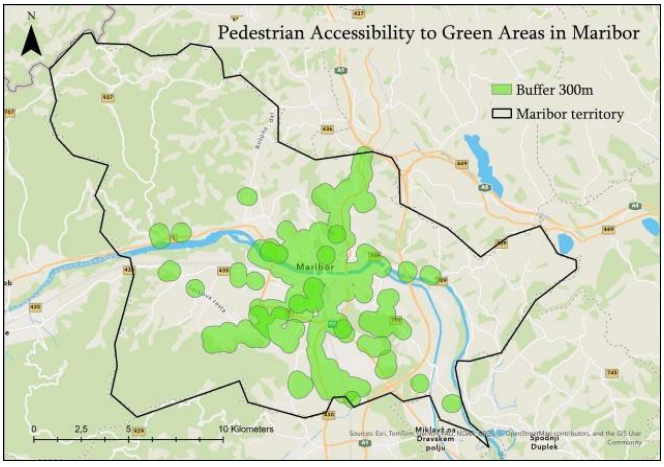

Figure 8: Map of the pedestrian accessibility to green areas in Maribor.
Source: S. Yakovlieva, 2025

Figure 8 analyses pedestrian accessibility to green areas using a 300-metre buffer. This threshold is based on the "3-30-300" rule, which states that for high-quality urban life, every resident should have access to a green area within 300 metres of

their home (Lopez et al., 2025). The pedestrian accessibility map illustrates the accessibility of urban green spaces. The analysis excludes forests and green areas that are not designed or equipped for public use, i.e., spaces without urban infrastructure such as parks, paths, or recreational facilities. The buffer zone was created to show how city residents can access and utilise green spaces within the urban environment.

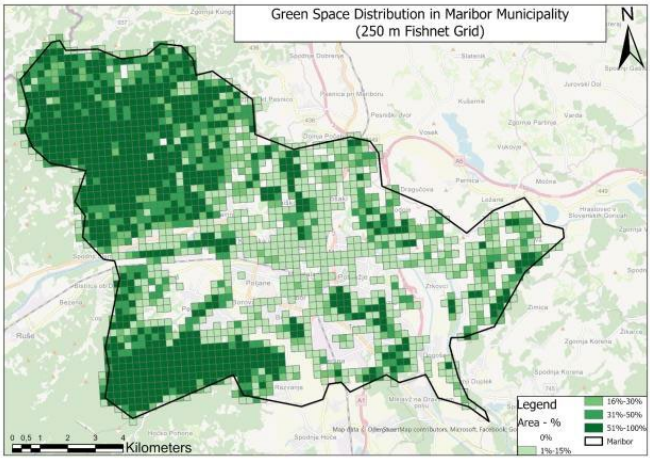

Figure 9: Map of green space distribution in Maribor.
Source: E. Cherkez, 2025

The map in Figure 9 utilises a fishnet grid approach to present the distribution of green spaces in the municipality of Maribor. The study area was delineated using a uniform grid of 250 x 250 m cells (6.25 ha), which was then clipped to the municipal boundary. For each cell, the proportion of green space was calculated by intersecting the grid with green space polygons and expressing the result as a percentage of the cell area.

The map utilises a graduated colour scheme, where lighter shades represent cells with minimal or no green space, while darker shades indicate higher levels of green coverage. The results reveal a clear spatial pattern: peripheral areas of Maribor are characterised by high percentages of green space, mainly due to forests and agricultural land, whereas the urban core shows limited coverage, reflecting dense built-up areas.[2]

The previous cartographies aimed to assess the ecological structure of the city of Maribor and evaluate the overall quality of its urban environment using spatial data. The analysis focused on the distribution and accessibility of green spaces, ecological zones, and protected areas designated under the Natura 2000 network. Collectively, these datasets provide a comprehensive understanding of how green areas are integrated into the broader ecological framework of the city and the extent to which they are institutionally protected at both national and European Union levels. The integration of accessibility maps into the study enabled a detailed examination of how urban residents can physically access and utilise green spaces. This component highlights the interconnection between green infrastructure and quality of life in Maribor, emphasising the role of ecological areas in enhancing the physical and psychological well-being of the population.

4 The perception of the ecological network in Maribor

In addition to the previous mapping of the ecological networks, we conducted interviews with people present in the streets of Maribor to collect their perceptions of green areas. During the week of the summer school, we interviewed a total of 20 individuals–11 women and 9 men–resulting in a relatively balanced sample. Most participants are either residents (8 people) or commuters, including students (9 people), while only 3 respondents are visitors. Walking (7 people) and driving (6 people) are the most common transport modes, followed by public transport (4 people) and cycling (3 people), indicating that active mobility is important, but car use still plays a significant role.

Most respondents use green spaces in Maribor very frequently (several times a week or daily), showing that nature and parks are an essential part of everyday life in the city. The Drava riverbanks (9 mentions), parks (7), Pohorje (6), and Piramida (6) emerged as the most popular natural destinations, highlighting their importance for the city's ecological network and for connecting residents with nature. At the same time, the main reasons stopping people from visiting these areas more often are lack of time (5 people), work or studies (5), and weather conditions (3), suggesting that external and personal factors are more significant barriers than accessibility or safety. When asked about the most important benefits of green areas, respondents emphasised clean air (9 mentions), shade (6), recreation (6), and relaxation (6), underlining that people value both the environmental and well-being functions of urban green spaces.

For some questions, respondents provided multiple answers, which is why the total number of mentions exceeds the number of participants.

5 Discussion

The first part of the research, spatial analysis, demonstrates the current state of the ecological network of Maribor. The outcome illustrates a positive picture of how these systems are functioning. The second part complements the previous one, providing information on how people living or temporarily staying in Maribor use services and how they evaluate their quality. Overall, we observe a positive situation in both aspects: what the system provides and how communities use it and feel. The lack of time is often mentioned as a constraint to frequenting green areas, suggesting that incorporating green spaces into everyday spaces could enhance the benefits of green corridors.

Unfortunately, time constraints restricted the scope of our study. A potential future part of the research could delve into specific areas of Maribor and examine them in greater detail. Biological aspects, such as the distribution of biodiversity and species, as well as the health of residents, could also be included. Nevertheless, the resources and data we gathered offer an overall view of the city.

6 Conclusion

This research was initiated by emphasising the significance of ecological networks and ecosystem services in shaping sustainable urban development in Maribor. By combining spatial analysis with the perceptions of residents, commuters, and visitors, it becomes evident that green corridors, protected areas, and accessible urban green spaces play a key role not only in maintaining ecological connectivity but also in supporting the well-being of local communities. The positive alignment between the current state of the ecological network and the way people use and value these services underlines the city's potential to strengthen resilience against environmental and social challenges, especially since the literature study demonstrates that ecological infrastructure is not only a matter of biodiversity conservation but also a foundation for healthier, more inclusive, and climate-adapted urban living.

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